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The role of clippings in the maintenance of a Kentucky bluegrass turf.

Harry Peter Wood
University of Massachusetts Amherst

The Role of Clippings in the Maintenance of a Kentucky bluegrass Turf

by

H. Peter Wood

B.S. University of Massachusetts

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TABLE OF CONTENTS

List of Tables

List of Figures

I. INTRODUCTION

With the increase in suburban living has come a tremendous increase in the number of new homes as well as the lawn areas surrounding them. Many of these lawns are poorly established on low fertility soil and are seeded to mixtures that contain substantial amounts of temporary grasses. These grasses may persist for only a short period of time, approximating three to four years. Even lawns in the Northeast that are seeded to the more permanent-type lawn mixtures such as Kentucky bluegrass and red fescue are often neglected once established. A bluegrass-fescue lawn mixture requires a yearly addition of three to four pounds of actual nitrogen per 1000 sq. ft. applied in a complete fertilizer and periodic applications of lime to keep the soil pH at approximately six. Unfortunately most lawns in a season receive either very little or no lime and perhaps only one to two pounds of nitrogen per thousand square feet. Nevertheless, many of these lawns that lack an effective liming and fertilization program have a very attractive and healthy appearance year after year.

It could be quite possible that lawns and turf areas persist and are attractive because clippings left on the turf act in the same manner as an effective organic fertilizer. As clippings slowly decompose or breakdown, elements such as nitrogen, phosphorus, potassium, calcium, magnesium and various minor elements which are necessary for plant growth, are released.

Supporting evidence for this was found by Gilbert et. al. (16) studying complete fertilizers and their effect on turf. In their studies they found that turf fertilized in 1954 but not in 1955 showed a substantial increase in weights of harvested clippings. The increase in clipping weights of the treated plots over the check plots persisted through the growing season and was attributed to the addition of nitrogen derived from retained clippings. They also indicated that supplemental summer fertilization applications are more necessary when clippings are removed than when they are retained.

Thus, it appears that leaving clippings on the turf may contribute substantially to the nutrition of the grass. The present investigation was undertaken to determine (1) the effect of clippings on the appearance, growth, incidence of disease, contamination by weeds, and thatch development of the turf and (2) the value of clippings as a source of plant nutrients, particularly nitrogen and potassium.

II. REVIEW OF LITERATURE

A. The Composition and Fertilizer Value of Grass Clippings.

Many experiments have been conducted on Kentucky bluegrass. Each has dealt with some facet of the growth, development, or persistance of this turfgrass. Some aspects such as the value of returned clippings to the stand have not been completely investigated as is evident by the small number of reports on the subject in scientific literature.

Growth factors which influence the yield of grass clippings must be understood and skillfully manipulated to insure controlled experiments. Nitrogen, one of the most important fertilizer elements needed by turf, encourages the vigorous production of grass vegetation. Essential elements which are not readily available from the soil but are needed for grass development can be supplemented by the use of either inorganic or organic fertilizers. Grass clippings being organic in nature are similar to natural organics and can serve as a source for nitrogen as well as other essential plant nutrients.

Many experiments have been conducted to determine the nutritive content of grass clippings. Bear and Cox (3), Goss (18), Noer, Wilson and Hamner (37), and Watson (46) have each performed analytical experiments on grass clippings and found that, on an average, these clippings contained five percent nitrogen. In an experiment carried out by Waksman and Tenny (45), they determined that fifty percent of the nitrogen found in fresh green grass is converted into usable forms and made available to the plant within seven days. While studying the effects of various types of fertilizers on a number of different turfgrass species, Uhlrogge (40) pointed out that a ton of dry grass from each of the species contained from twenty to eighty pounds of nitrogen, four to ten pounds of phosphate, and twenty to sixty pounds of potash. The removal of a ton of clippings, containing this sizable amount of nutrients, caused an extensive loss of nutrients to the turf stand. He further pointed out that turf does not fully utilize the entire amounts of nutrients supplied in fertilizer applications.

Elliot (12) concluded from his clipping trials that from a permanent bluegrass sod the total yield of dry matter varies inversely with the number of times the grass is cut during the growing season. Higgins (24) suggested mowing often so that clippings may be left on the stand. These thus donáting organic matter containing nutrients.

One of the early beliefs concerning plant nutrition was that organic matter, as such, is directly absorbed by higher plants. This early theory, however, was discarded following the work of the German chemist, Liebig, more than one hundred years ago. Since Liebig's time, many investigators have shown that as organic matter is decomposed or broken down essential plant nutrients are released in forms available to growing plants.

The rapidity of decomposition of organic matter and the rate of release of nutrients as seen by Alexander (25), Holtz and Vandecaveye (29), Lyon et al. (25), and Pinch et al. (39) is closely related to the carbon-nitrogen ratio. They each agree that most organic residues entering the soil carry large amounts of readily oxidizable carbon and relatively small amounts of total nitrogen, thus a wide carbon-nitrogen ratio. In the presence of such easily acquired energy from carbon there invariably occurs a rapid multiplication of the general-purpose, heterotropic, decay organisms, bacteria, fungi and actinomycetes. This is accomplished by a rapid loss of carbon dioxide as a waste product from the decay organisms. The nitrogen is largely utilized at this stage due to the microbial demands for this element as new cells develop and protoplasmic synthesis takes place. As a consequence, most of the nitrogen is retained in the soil within the heterotropic flora while carbon is lost as carbon dioxide. The carbon-nitrogen ratio becomes smaller as the amount of easily available carbon decreases. As a result, the activities of the general-purpose heterotropic organisms are slowly curtailed. The microbial demand for nitrogen, therefore, markedly diminishes and as a result ammonia is released by ammonification. Nitrification may now take place and nitrate nitrogen is produced. As the slow decomposition process continues both carbon and nitrogen are subject to loss and the ratio is stabilized until the addition of more organic matter.

B. The Fertilization of Turfgrass

The major fertilizer elements, N, P, and K may be considered as individual growth factors, but their effects are interrelated. All are essential for the growth of good quality turf.

Arminger (2), Goetz (17), Musser (35), and Wesnoski (47) each have shown that there is a difference in the rate of nitrogen release from organic and inorganic fertilizer sources. Results of their studies with turf fertilizer show a much shorter period of effectiveness for the inorganics as compared to the organics. DeFrance and Odland (10) stated that applications of only inorganic fertilizer did not produce a uniform quality turf throughout the growing season. North, Odland and DeFrance (38) in developing quality ratings for turf showed that organic fertilizer was superior to mineral fertilizer although turf developed more slowly.

Work conducted at Rhode Island by DeFrance (8) on the use of fertilizer for golf course turf, tennis courts and bowling greens has revealed that the organic fertilizers should supply at least one-third of the applied nitrogen per year. He found that turf responded to applications of 10-6-4, 10-5-0 or similar grade fertilizers.

Garber (15), Harrison (21), Monteith (32) and Noer (36) each have shown the detrimental effects of insufficient amounts of nitrogen on the growth and quality of turf. Failure to maintain adequate levels of nitrogen resulted in weak turf that permitted weed infestation and increased the susceptibility to certain diseases.

Lewis and Land (27) observed an increase in intensity of green foliage color of grass with each additional increment of nitrogen applied during the growing season. Nitrogen applications increased the average calcium content of turfgrass and gave a slight but significant increase in the average phosphorus content of the grass foliage.

Kentucky bluegrass is well adapted for permanent lawns if adequate levels of soil fertility are manitained (42). The seperate observations of Duich (11), Foley (14) and Madison (31) in experiments made on turf management indicate the necessity for constant and adequate supplies of available nitrogen to insure vigorous growth of Kentucky bluegrass as well as that of other turfgrass species.

Musser (33) stated that grasses should be fertilized according to the specific requirements of such species. He recommended for Kentucky bluegrass one pound of nitrogen per thousand square feet for each month of the growing season except July and August; 1.5 to 2.0 pounds of phosphate annually and very little potassium except for grasses grown on sandy soils or in mucks. Musser (34) also recommended the use of organic fertilizers to obtain lasting effects of nitrogen and inorganic sources of fertilizer nitrogen to obtain fast responses. He further suggested that a soil pH of six to seven is conducive to the growth of bluegrass. In MacLeod's thesis (30) the recommended fertilizer requirements for the healthy, vigorous growth of Kentucky bluegrass in most Massachusetts soils is about one thousand pounds of a 10-8-4 per acre annually.

DeFrance (9) suggested that a fall application of fifteen to twenty pounds per thousand square feet of a 10-6-4 or 10-5-0 be applied to home lawns. When this application is made after a frost, crabgrass is not encouraged. DeFrance also indicated that a pH of around six is appropriate for the growth of Kentucky bluegrass.

The principal measure of response to nitrogen fertilization, as reported by Davis (7) are: the yield of clippings at intervals during the growing season, the percent nitrogen (dry-weight basis) in the clippings, the weed content of each plot as measured annually, and the color as observed at intervals during the season.

It is expected that varying fertilizer applications, clipping frequencies, and the removal or non-removal of clippings will have an effect not only on the foliage but also on the root system and on the rate of development of the plant.

C. Nitrogen Fertilization and Root Development

In separate work done by Thoughton (44) and Bredakis (4) it was shown that grass plants grown at low levels of available soil nitrogen produced well-developed root systems. It was observed that the roots of such plants were much coarser than those produced by plants grown at high levels of soil nitrogen. The effects of various fertilizer applications on bluegrass roots was studied by Haynes (23) in New Jersey. He found the root weights in the upper two inches of the soil increased but root weights below the two-inch level decreased as fertilizer applications were increased.

Root development and top growth of turf are affected not only by management factors such as fertility levels, clipping heights, etc., but also by natural factors.

D. Environmental Factors

Together with a fertilization program, growing good turf requires a thorough knowledge of the relationship and responses of grass to its environment. Sprague et al. (43), working on pasture grass improvement, indicated that initial growth of bluegrass in spring was due to the accumulation of moisture during the winter and that reduced growth usually experienced in July and August was the result of chronic moisture deficiency.

Brown (5) observed seasonal variations in bluegrass growth. He noted that, even with irrigation, bluegrass growth was reduced during the summer months. Brown also noted the effect of temperature on bluegrass (6).

He found that the growth rate of the grass was closely related to soil temperature at the one-half inch depth. No growth occurred until the soil at this depth had warmed to 50°F. Maximum growth occurred at 60° - 64°F. He also found that crude protein content declined with a rise in air temperature from 40°F to an optimum growth temperature of 60°F and then increases as temperatures rose above 60°F. He determined that high daytime temperatures appeared to be counter-balanced by low night temperatures in their effects on bluegrass chemical composition. In another experiment concerning temperatures, Harrison (20) concluded that optimum air temperature for Kentucky bluegrass growth was 60°F. At 100°F bluegrass exhibited very little growth and was severely damaged. Long, bright days reduced production of leaf shoots but accelerated rhizome production.

Evans and Watkins (13) concluded from their work on day length that heavy spring growth of bluegrass was the result of long days while short fall days reduced grass growth. Under the relatively long days of late spring and early summer, Kentucky bluegrass grew in a nearly upright position, and internodes became elongated. In comparison, grass grown under short fall days had twice as many shoots per plant, and they grew more nearly in a decumbent position.

Juhren _et al._ (26), studying grass responses to variations in light intensity, found that Kentucky bluegrass had optimum growth at 800-foot candles (the test included an intensity range of 400-12,000-foot candles) and that an eight hour day was detrimental to bluegrass.

Musser (34) states that thatch development is undesirable when organisms do not decompose this organic matter as rapidly as it accumulates. The mat may become so dense that a water-tight surface thatch is formed.

III. GREENHOUSE STUDY

A. Procedures

1. Growing the Turf

In March of 1966 an experiment was initiated in a greenhouse to determine the nutritive effect of Kentucky bluegrass, Poa pratensis L., clippings on nonfertilized turfgrass growing in boxes.

A one-half inch layer of granite chips was placed in each of 40 wooden boxes six by twelve by six inches. The chips were used to prevent soil seepage from the drain holes in the box bottoms. Approximately nine pounds of low-fertility, loamy-sand soil were then added to each box. The soil, uniformly compacted, filled each box to within one inch of the top. A mechanical analysis showed that the soil was 81% sand, 14% silt and 5% clay (41).

Soil nutrient tests, determined by the Morgan method (28), indicated that calcium, magnesium, nitrate nitrogen, and ammonium nitrogen levels were low whereas potassium and phosphorus were medium. The initial pH of the soil in each box was 4.7. It was adjusted to 6.0 by the addition of ground limestone (Table 1).

One gram of Kentucky bluegrass seed was planted to each box and covered with one-sixteenth inch of sand to hasten germination. Seeds in all boxes germinated in approximately 14 days.

2. Treatments

The boxes of turf were arranged to receive eight treatments. Each treatment was replicated five times. The treatments appear in (Table 2).

In addition to the initial pH adjustment, limestone was applied to each box of turf three times during the course of the experiment in an amount equivalent to 19 pounds per 1000 square feet.

3. Maintenance of the Turf

Each box of grass was given the equivalent of one acre-inch of water per week.

All boxes of turfgrass were maintained at a clipping height of one and one-half inches by using hand shears resting on and moving across a one-half inch template. The grass was clipped when it reached a two-and-one-half inch height. The clippings were then oven dried, and a gram sample from each harvest was saved for nitrogen analysis. The oven-dried samples were prepared for analysis by grinding each to a fine pulp in a Wiley intermediate mill. The percent nitrogen was determined by the Kjeldahl method (22).

The effects of the treatments on the amounts of available plant nutrients and pH of the soil in the boxes was determined periodically by the Morgan method and the glass electrode method respectively (Table 1).

On June sixth all boxes of turfgrass were moved out of doors. They were placed in a bed of damp sawdust to prevent dessication of plant roots. When natural precipitation was less than one acre-inch per week, the grass was irrigated.

At the conclusion of the experiment, a six-inch core of turf, four and one-half inches in diameter, was removed from each box with a golf course cup cutter. Roots in each plug were washed free of soil and the length measured. The roots were then oven dried, ground and analyzed for phosphorus by the molybdovando phosphoric acid method according to the Cornell University analytical procedures as compiled by Grenling (19). Thatch depth was also measured and recorded. All data were statistically analyzed.

Table 1. Results of rapid soil test as affected by the treatments (Greenhouse Study).

	Treatments	Date of analysis	pH	Ca	K	P	Mg	NO_3	NH_4
Initial Soil Test		1/19/66	4.8	L	MH	MH	M	M	M
I	2 lb. actual nitrogen	5/23/66	5.2	L	M	M	M	L	L
II	Unfertilized turf plus clippings from 2 lb. N		5.3	L	L	M	L	L	L
III	4 lb. actual nitrogen		5.5	L	M	MH	MH	L	L
IV	Unfertilized turf plus clippings from 4 lb. N		5.4	L	M	J	M	L	L
V	7 lb. actual nitrogen		5.2	H	H	H	M	H	MH
VI	Unfertilized turf plus clippings from 7 lb. N		5.5	L	M	MH	MH	L	L
VII	9 lb. actual nitrogen		5.2	H	H	H	M	H	MH
VIII	Unfertilized check plot		5.0	L	L	M	L	L	L
I	2 lb. actual nitrogen	7/19/66	5.2	L	M	M	M	L	L
II	Unfertilized turf plus clippings from 2 lb. N		5.4	L	L	M	M	L	L
III	4 lb. actual nitrogen		5.5	L	M	MH	MH	L	L
IV	Unfertilized turf plus clippings from 4 lb. N		5.5	L	M	M	MH	L	L
V	7 lb. actual nitrogen		4.9	M	MH	H	MH	L	L
VI	Unfertilized turf plus clippings from 7 lb. N		5.5	L	M	MH	MH	L	L
VII	9 lb. actual nitrogen		4.9	M	MH	H	MH	L	L
VIII	Unfertilized check plot		5.8	L	L	L	MH	L	L
I	2 lb. actual nitrogen	9/10/66	5.0	L	L	L	M	L	L
II	Unfertilized turf plus clippings from 2 lb. N		5.2	L	L	L	M	L	L
III	4 lb. actual nitrogen		4.9	L	L	L	L	L	L
IV	Unfertilized turf plus clippings from 4 lb. N		5.3	L	L	M	M	L	L
V	7 lb. actual nitrogen		5.0	L	L	L	L	L	L
VI	Unfertilized turf plus clippings from 7 lb. N		5.2	L	L	L	M	L	L
VII	9 lb. actual nitrogen		5.8	L	L	M	M	L	L
VIII	Unfertilized check plot		5.2	L	L	M	M	L	L

* L - Low
M - Medium
MH - Medium High
H - High

Table 2. Dates of treatment applications with types and amounts of materials used in the greenhouse

Treatments		Fertilizer Applications (Time and Rate of N Per 1000 Ft^2)		Clipping Applications (Date and Dry Weight)*	
I	2 lbs. Actual N	Apr.	1 lb. N. (10-10-10)		
		May	1 lb. N. (8-6-4)**		
II	Clippings from I			May	2.08 Gms.***
				June	.62 Gms.
				July	.42 Gms.
				Aug.	.94 Gms.
				Sep.	.78 Gms.
III	4 lbs. Actual N	Apr.	2 lbs. N. (10-10-10)		
		May	1 lb. N. (8-6-4)		
		July	1 lb. N. (10-10-10)		
IV	Clippings from III			May	1.68 Gms.
				June	.74 Gms.
				Aug.	.86 Gms.
				Sep.	.78 Gms.
				Oct.	.57 Gms.
V	7 lbs. Actual N	Apr.	2 lbs. N. (10-10-10)		
		May	2 lbs. N. (8-6-4)		
		July	2 lbs. N. (10-10-10)		
		Aug.	1 lb. N. (8-6-4)		
VI	Clippings from V			May	2.14 Gms.
				June	2.01 Gms.
				July	1.32 Gms.
				Aug.	1.28 Gms.
				Sep.	1.42 Gms.
				Oct.	1.04 Gms.
VII	9 lbs. Actual N	Apr.	2 lbs. N. (10-10-10)		
		May	2 lbs. N. (8-6-4)		
		July	2 lbs. N. (10-10-10)		
		Aug.	2 lbs. N. (8-6-4)		
		Sep.	1 lb. N. (8-6-4)		
VIII	Control	None		None	

* See Appendix tables 2,3,4,5,6,7 and 8 for weights of clippings applied in respective treatments.

** Nitrogen in 10-6-4 was in part organic.

*** Average weight of clippings applied to each plot of turfgrass.

B. Results and Discussion

Appearance of the Turf

The appearance of the turfgrass in all boxes, including density of the stand and color, was the same for the first fifteen days following germination. It appears that this was due to the initial fertility in the soil, since the soil had not yet been altered by fertilization. The first noticeable difference appeared three days after treatment application. The grass in all the fertilized boxes was dark green, and these stands were much denser. The unfertilized turf looked chlorotic, an appearance which indicated a nitrogen deficiency as was indicated in the tissue analysis. Chlorosis was also a result of the nutrient depleted soil as was determined from soil tests. The controls remained chlorotic throughout the experiment.

One week after clippings from Treatment I, two pounds N, Treatment III, four pounds N, Treatment V, seven pounds N, were applied to unfertilized turf in Treatments II, IV, and VI respectively, the turf in the latter boxes turned from a pale green to a dark green. Several days elapsed and the turfgrass in Treatment II again became chlorotic. A few days later the same symptoms were evident for grass in Treatments IV and VI. With each additional application of clippings, however, came an extended lapse of time before the reappearance of the light colored topgrowth.

The turf which received fertilizer applications turned dark green within three days of application. The color persisted throughout the growing season. There were slight variations in the intensity of the green color as a result of the rates of fertilizer application. The greater the rate, the darker the green color in the turf.

Growth of the Turf

The turf that received treatments of clippings containing higher amounts of nutrients developed better than the turf treated with clippings low in nutrients. As shown in Tables 2, 3, and 4 there was a substantial increase in the clipping weights taken from turf receiving fertilizer or clippings as compared to their respective controls.

There was also a difference in the harvest weights between turf which received fertilizer and turf which received only clippings. Initially, fertilized turf produced heavier topgrowth than the grass that received clipping treatments, but the influence of the fertilizer was short termed. The available nitrogen appeared to be rapidly exhausted by the plants or lost by leaching.

In this experiment light seasonal applications of fertilizer, two pounds of actual nitrogen per thousand square feet, produced poor quality turf. Turf heavily fertilized, four pounds or more of actual nitrogen per thousand square feet, developed turf which was uniform and healthy throughout the growing season. The quality of all the grass plots which received just clippings improved slowly as the season progressed. This was perhaps due to the slow release of nutrients through clipping decay.

During the summer months the growth of Kentucky bluegrass in the greenhouse experiment was depressed. Since irrigation did not eliminate this midsummer depression of yield, Brown's (5) findings -- reduction in growth due to superoptimal temperatures -- are substantiated. As a result, harvest data was incomplete, and only the results of the last three months were analyzed statistically.

Disease Incidence

Early in the experiment a slight incidence of leaf spot was apparent on the turfgrass, but lasted only for a short time. A fungus, identified as a species of Fusarium, infected the clippings that were applied without drying and grinding, but did not infect the growing grass plant. Once these clippings were removed, dried, ground, and then reapplied, there was no trace of the organism.

Weed Infestation

The turfgrass in the greenhouse study that received clippings low in nutrients as their source of fertility were, for the most part, very weedy. The only exception was Treatment VI, which received clippings from the seven pound nitrogen treatment. The grass in this treatment has only moderate infestation of weeds and was comparable to Treatment III, four pounds of nitrogen. With an increase in fertilizer increments, the weed infestation decreased, and it was apparent that the weeds could not compete with the well-fed, healthy grass.

Thatch Development

The occurrence of varying amounts of thatch was evident in the greenhouse study. Clipping may be the cause of small amounts of this thatch, and probably over an extended period of time, they would account for a greater amount of it. The degree of this formation would depend on the rate of the organic matter decay.

According to Musser (34), thatch may cause an unfavorable water and air tight layer, or may develop an environment favorable for the growth of disease-causing organisms.

The accumulation of thatch (Table 3) in the turf which had received no fertilizer or clippings, Treatment VIII, and the grass which had received two pounds of nitrogen, Treatment I, was slight -- 0-1/4 inch. This may be due to root decay and sloughing off, as well as, the death and decay of grass blades and weeds. Thatch accumulation was medium, 1/4 - 3/4 inch, in respective turf plots that had received four, seven, and nine pounds of nitrogen as fertilizer. Treatment II, unfertilized turf plus clippings from Treatment I, had a medium amount of thatch. Grass receiving treatment clippings from the turf fertilized with seven pounds of nitrogen and turf plots which received nine pounds of nitrogen had a medium amount of thatch (Figure 1).

Root Development

Root length was greater in the low fertility treatments. As fertility increased, either by direct fertilization or by the addition of clippings, the texture of the roots became fine; they appeared very healthy, but their length was reduced. Turf grown on low-fertility soil produced long, coarse, corky roots (Figure 2). The differences in phosphorus content, not P_2O_5, of the root tissue were not significant (Table 4).

It is possible that phosphorus in the applied fertilizer and phosphorus in the organic matter were immobilized in complexes near the soil surface and were made available to the plants. Furthermore, some phosphorus found in the roots was probably present in the soil prior to the turf establishment.

Plant Nutrients

The results of the tissue analysis are not complete for the greenhouse study. The data that is available supports the theory that retained grass clippings do add substantial amounts of nitrogen to the turfstand.

Unfertilized turf that received clippings as its treatment produced top-growth which was rather low in nitrogen in August. These amounts increased substantially, except Treatment IV, in September and in October the amounts were all double the amounts found in August.

It is apparent from the data that there was a slow increase in the amount of nitrogen in the topgrowth of the turf which received only clippings as their treatment (Table 5). This slow improvement was probably due to the breakdown of the clippirgs and release of nutrients.

The nitrogen content of the turf which received fertilizer applications decreased as the season progressed (Appendix Table 9) except under high fertilization treatments. This was probably a result of leaching and exhaustion of the nutrient supply by plant use.

As the amounts of applied fertilizer were increased and as the fertility level of the source of applied clippings was increased so were the amounts of nitrogen found in the harvested topgrowth.

The data on potassium is not available for the greenhouse study but conclusive results were found in the field experiment.

The results of the greenhouse experiment were not as revealing as those of the field study. This is attributed to the inadequacies in the physical conditions of the greenhouse.

Figure 1. Thatch accumulation as affected by low nitrogen, high nitrogen and returned clippings (Greenhouse Study).

Figure 2. Development of Kentucky bluegrass roots as affected by low nitrogen no clippings, low nitrogen clippings added and high nitrogen.

Table 3. Observation of thatch thickness as affected by treatments. (Greenhouse Study).

	Treatment	Results*
I	2 lb. actual nitrogen	Slight
II	Unfertilized turf plus clippings from 2 lb. nitrogen	Medium
III	4 lb. actual nitrogen	Medium
IV	Unfertilized turf plus clippings from 4 lb. nitrogen	High
V	7 lb. actual nitrogen	Medium
VI	Unfertilized turf plus clippings from 7 lb. nitrogen	Medium
VII	9 lb. actual nitrogen	Medium
VIII	Control**	Slight

* slight 0-1/4 inch, medium 1/4-3/4 inch, medium-high 3/4-1 1/4 inch and high 1 1/4 inch and up.

** Thatch measured at the initiation and termination of the experiment.

Table 4. Treatments and percent phosphorus in Kentucky bluegrass roots (Greenhouse Study)

Treatments		Series 1	2	3	4	5	Total	Treatment Mean*
I	2 lb. nitrogen	.81	.81	.93	.82	1.03	4.50	.90
II	Unfertilized turf plus clippings from I	.84	.91	.79	.81	.76	4.11	.82
III	4 lb. nitrogen	.73	.98	.83	.94	.92	4.40	.88
IV	Unfertilized turf plus clippings from III	.85	.78	.84	.97	.80	4.24	.88
V	7 lb. nitrogen	.91	1.03	.95	1.04	1.03	4.96	.99
VI	Unfertilized turf plus clippings from V	.92	.97	1.09	.94	.94	4.87	.97
VII	9 lb. nitrogen	.99	.75	1.12	1.18	.93	4.97	.99
VIII	Control	.82	.90	.88	.87	.80	4.27	.85

* No significant difference

Table 5. Grams of nitrogen in Kentucky bluegrass clippings on a dry weight basis (Greenhouse Study).

Treatments*		Harvest Dates Aug. 8	Sept. 13	Oct. 19	Total	Treatment Mean
VII	9 lbs. actual nitrogen	8.17a	8.48a	8.65a	23.30	8.43a
V	7 lbs. actual nitrogen	5.20b	5.83b	3.64b	14.67	4.89b
VI	unfertilized turf plus clippings from 7 lb. N	1.25c	2.17c	3.94c	7.36	2.45c
IV	unfertilized turf plus clippings from 4 lb. N	1.44c	1.45c	2.55bc	5.44	1.81cd
II	unfertilized turf plus clippings from 2 lb. N	0.57c	0.68c	1.56bc	2.81	0.94cd
VIII	unfertilized control	0.33c	0.64c	0.78c	1.75	0.58d

Treatment means followed by the same letter do not differ significantly at the 0.05 level using Duncan's multiple range test.

*Treatment I and III not included due to insufficient topgrowth to per- nitrogen analysis.

Analysis of Variance for Table 6.

Source	df	Mean Square	F
Treatments	5	26.8156	41.50**
Harvest	2	0.7235	1.12
Interaction Treat. X Harvest (Error)	10	0.6461	

** Significant at 0.01 level

IV. FIELD STUDY

A. Procedures

1. Plot-plan

The nutritive effects of turf clippings from fertilized turf grass applied to unfertilized turf were further evaluated during the 1967 growing season on an established 625 square foot plot of Delta Kentucky bluegrass. *Poa pratensis* L. var. Delta.

The stand, established for at least two years, was growing on a sandy loam soil located on the University of Massachusetts, Montague Farm. Prior to the initiation of this experiment, the turf received about two pounds of actual nitrogen per 1000 square feet annually and one treatment of lime at the rate of 50 pounds per 1000 square feet. Soil nutrient tests indicated a high level of calcium, phosphorus and magnesium, a medium level of nitrate nitrogen and a low level of potassium and ammonia nitrogen. The soil pH was 6.9 (Table 16).

On May 27, 1967 the turf area was mowed to one and one-half inches and all clippings removed. A 25 by 25 foot area was then divided into 18, 12 foot by 21 inch plots. Treatments consisting of applications of fertilizer, fertilizer and grass clippings and clippings alone were each applied to three replicated plots randomized within the area.

2. Treatments

The six treatments appear in (Table 7).

All plots were maintained at a one and one-half inch height with a reel mower. Natural precipitation was utilized throughout the experiment. The effects of the treatments on the available nutrients in the soil and the soil pH of each plot was determined periodically using the Morgan method and a glass electrode pH meter. Thatch was measured and the data recorded as high, medium high, medium and slight (Table 8).

Three grams of oven dried clippings were saved from each treatment harvest. They were ground in a Wiley intermediate mill and analyzed for nitrogen and potassium content by the Kjeldahl and flame photometer method respectively.

The percent nitrogen within the three grams of dried clippings taken from each plot was converted to pounds of actual nitrogen per 1000 square feet. The percent potassium in the topgrowth was also converted to pounds per 1000 square feet. Total amounts of actual nitrogen and potassium within the harvested clippings are listed in (Table 9, 10), and the percents nitrogen and potassium in each harvest are shown in the Appendix table 10 and 11.

Table 6. Results of the chemical soil tests from the Delta Kentucky bluegrass plots

	Treatment	Date	pH	Ca	K	P	Mg	NO_3	NH_4
				Tests Performed					
	Initial Soil Test	5/1/67	6.9	H	L	H	H	M	L
I	Unfertilized Check Plot	6/29/67	7.2	L	H	H	H	M	L
III	Unfertilized turf plus clippings from 2 lb. N		7.0	L	H	H	H	L	L
II	2 lb. actual nitrogen		7.1	MH	MH	H	H	M	L
V	Unfertilized turf plus clippings from 4 lb. N		7.1	H	H	H	H	M	L
IV	4 lb. actual nitrogen		7.0	M	H	H	H	M	M
VI	4 lb. actual nitrogen plus own clippings		6.9	MH	H	H	H	L	L
I	Unfertilized Check Plot	8/1/67	7.0	H	L	H	H	L	L
III	Unfertilized turf plus clippings from 2 lb. N		7.0	H	L	H	H	L	L
II	2 lb. actual nitrogen		6.5	MH	L	H	H	L	L
V	Unfertilized turf plus clippings from 4 lb. N		6.9	H	L	H	H	L	L
IV	4 lb. actual nitrogen		6.9	H	L	H	H	L	L
VI	4 lb. actual nitrogen plus own clippings		6.8	H	M	H	H	L	L
I	Unfertilized Check Plot	8/17/67	7.0	MH	L	H	H	L	L
III	Unfertilized turf plus clippings from 2 lb. N		6.9	MH	L	H	H	L	L
II	2 lb. actual nitrogen		6.6	MH	L	H	H	L	L
V	Unfertilized turf plus clippings from 4 lb. N		7.0	H	L	H	H	L	L
IV	4 lb. actual nitrogen		6.8	H	L	H	H	L	L
VI	4 lb. actual nitrogen plus own clippings		6.8	H	M	H	H	M	M

L -Low
M -Medium
MH -Medium High
H -High
VH -Very High

Table 7. Dates of treatment applications with types and amounts of materials used in the field study

Treatments		Dates of Fertilizer Applications and Grade (Lbs. Actual N per 1000 ft^2)	Clipping Application (Dry Wt. in Gms.)**
I	Control	None	None
II	2 lbs. actual N	May 1 lb. (10-10-10) June 1/2 lb. (10-6-4)* Aug. 1/2 lb. (10-6-4)	
III	Clippings from II		51.4
IV	4 lbs. actual N	May 2 lbs. (10-10-10) June 1 lb. (10-6-4) Aug. 1 lb. (10-6-4)	
V	Clippings from IV		59.0
VI	4 lbs. actual N and own clippings returned	May 2 lbs. (10-10-10) June 1 lb. (10-6-4) Aug. 1 lb. (10-6-4)	68.7

* Nitrogen in 10-6-4 was in part in organic form

** The means of eleven harvests. For dates and amounts see Appendix, Table 1A, 2A, 3A, 4A, 5A and 6A

Table 8. Observations made on thickness of thatch (Field Study)

Treatment		Results*
I	Control**	Slight**
II	2 lbs. actual nitrogen	Medium
III	Clippings from II	Slight
IV	4 lbs. actual nitrogen	Medium High
V	Clippings from IV	High
VI	4 lbs. actual nitrogen plus own clippings	High

* Slight 0-1/4 inch, medium 1/4-3/4 inch, medium high 3/4-1 1/4 inch, and high 1 1/4 inch and up.

** Thatch measured at the initiation and termination of experiment.

Table 9. Total amounts and source of nitrogen in pounds per 1000 ft^2 applied to and removed from the plots of grass during the experiment.

Treatment No.	Nitrogen Applied in Fertilizer	Nitrogen Applied in Clippings	Total Nitrogen Applied	Nitrogen Removed in Clippings
I Control	0	0	0	1.7 lbs.
II 2 lbs. N	2 lbs.	0	2 lbs.	2.3 lbs.
III Clipping II	0	2.3 lbs.	2.3 lbs.	2.1 lbs.
IV 4 lbs. N	4 lbs.	0	4 lbs.	3.0 lbs.
V Clippings III	0	3 lbs.	3 lbs.	2.2 lbs.
VI 4 lbs. N plus own clippings	4 lbs.	3.1 lbs.	7.1 lbs.	3.1 lbs.

Table 10. Total amounts and source of actual potassium in pounds per 1000 ft^2 applied to and removed from plots of grass during the experiment.

Treatment No.	Potassium Applied in Fertilizer	Potassium Applied in Clippings	Total Potassium Applied	Potassium Removed in Clippings
I	0	0	0	2.9 lbs.
II	1.6 lbs.	0	1.6 lbs.	3.0 lbs.
III	0	3.0 lbs.	3.0 lbs.	2.9 lbs.
IV	3.2 lbs.	0	3.2 lbs.	3.2 lbs.
V	0	3.2 lbs.	3.2 lbs.	2.9 lbs.
VI	3.2 lbs.	3.1 lbs.	6.3 lbs.	3.1 lbs.

B. Results and Discussion

Appearance of the Turf

The color of the grass in the entire turf area was dark green at the initiation of the experiment and remained as such throughout the study regardless of the treatments.

The ever present green color in the turf was probably due in part to ample natural precipitation. There was an average of 3.68 inches of rain in June and August and 5.24 inches in July (Appendix Table 12). There was never any evidence of detrimental effects to the turf as a result of inadequate moisture.

Temperature throughout the growing season was also ideal. June, July and August were each characterized by many cool nights and warm days which are both conducive to the growth of bluegrass (Appendix Table 12).

Growing conditions in the field, ideal temperatures and sufficient moisture all contributed to the prevention of a depression in the growth and the lasting green color of the Delta Kentucky bluegrass throughout the summer months.

The slow breakdown of organic matter present in the soil before the initiation of the experiment and the selective addition of clippings throughout the experiment could also have accounted for the ever present green turf.

Growth of the Turf

The growth rate in the early summer of the turf which received fertilizer as a treatment was much greater than turf receiving only applied clippings as a treatment. This rate decreased very slowly until the first of July when the growth rate of the fertilized turf and turf receiving clippings approached the same level. The turf receiving clippings increased its growth rate far beyond that of the fertilized turf in the first two weeks of August.

In this experiment the fertilizer seemed to be exhausted either by plant use or leaching and apparently was unavailable to the plants during the latter portion of the season. On the other hand, turf receiving clippings progressively increased its growth throughout the summer. It appears that these clippings, through decay, released nutrients but only after an extended period of time (Figures 3 & 4, Table 11).

As was expected the yields from turf plots receiving large amounts of fertilizer were greater than those receiving less. The topgrowth from the grass which received clippings as a treatment increased as the fertility level as the source increased. (Appendix Tables 13 - 18).

Disease Incidence

There was never an incidence of disease on the turf throughout this study.

Weed Infestation

The turfgrass in the field experiment was for the most part weed free. The only exception was the turf in the control and Treatment II, two pounds of nitrogen. These two plots had a very minor infestation of weeds.

The general lack of weeds can probably be attributed to the healthy condition of the turf prior to the initiation of the study.

Thatch Development

Grass clippings can be detrimental since they add to the formation of thatch. Thatch can impede movement of air, water and fertilizer. Thatch can further affect a maintenance program by requiring specialized machinery for dethatching, Musser (34).

Thatch accumulation was slight in the control plots and in plots receiving Treatment III, clippings from II, (Table 8). All other treatments increased the depth of thatch in their respective plots. Grass receiving Treatment II, two pounds nitrogen, produced a medium amount of thatch. Turf receiving Treatment IV, four pounds nitrogen, had a medium high amount of thatch while turf receiving Treatment V, clippings from IV, and Treatment VI, four pounds of nitrogen and own clippings returned, had a high amount (Table 8).

Plant Nutrients

There was a noticeable increase in the amounts of nitrogen and potassium in the topgrowth of the turf which received fertilizer as a treatment immediately following the application. In all instances this was followed by a decrease in the amounts of nitrogen and potassium until the next fertilizer application.

The amounts of nitrogen and potassium in the topgrowth of the grass which received clippings as a treatment increased slowly throughout the growing season except during July 7 - 14. The greatest increases were evident in turf which received clippings from grass plots which in turn received larger fertilizer applications (Tables 12 & 13). This slow improvement was probably due to the breakdown of clippings and the subsequent release of nutrients.

When compared to the check plots, the unfertilized turf which received only clippings progressively increased in the amounts of nitrogen harvested in their clippings. Turf receiving clippings from Treatment II, two pounds of nitrogen, produced less nitrogen in its topgrowth than the control in June but in contrast in August three and one half times as much nitrogen. Turf receiving clippings from grass fertilized with four pounds of nitrogen produced the same amount of nitrogen in June but three times as much in August as compared to the control. This was apparently due to the release of nutrients as a result of the slow decay process.

Turf fertilized with two and four pounds of nitrogen produced clippings with three and six times as much nitrogen in them as compared to the control in June. This decreased to the same amount and twice as much nitrogen respectively in August.

The results are similar but somewhat less for the increases of potassium in the topgrowth (Table 14).

The clippings from the control plots contained 1.7 lbs. of nitrogen. The clippings from turf treated with 4.0 lbs. of nitrogen contained 3.0 lbs. of nitrogen, 1.3 lbs. more nitrogen than in the control.

The clippings of the turf treated with clippings from the plot treated with 4.0 lbs. of nitrogen contained 2.2 lbs. nitrogen or 0.5 lbs. more nitrogen than the control.

It is obvious that all of the nitrogen was not released, since this plot received 3.0 lbs. of nitrogen in the added clippings but produced only 0.5 lbs. nitrogen in its clippings more than the control. The difference of 2.5 lbs. of nitrogen apparently is tied up in undecomposed organic matter. Higher amounts of nitrogen might have been released from the undecomposed clippings had the time permitted (Tables 9 & 10).

The average percents of nitrogen and potassium in the harvested clippings of turf receiving clippings as a treatment were less than the amounts found in fertilized turf. These amounts paralleled but did not surpass, until late July, the amounts found in the fertilized turf (Appendix Tables 10 & 11).

The slow improvement again was probably due to the breakdown of clippings and the subsequent release of nutrients.

It is evident from the field study that clippings can and do hold and slowly release nutrients that are reused by the grass plots.

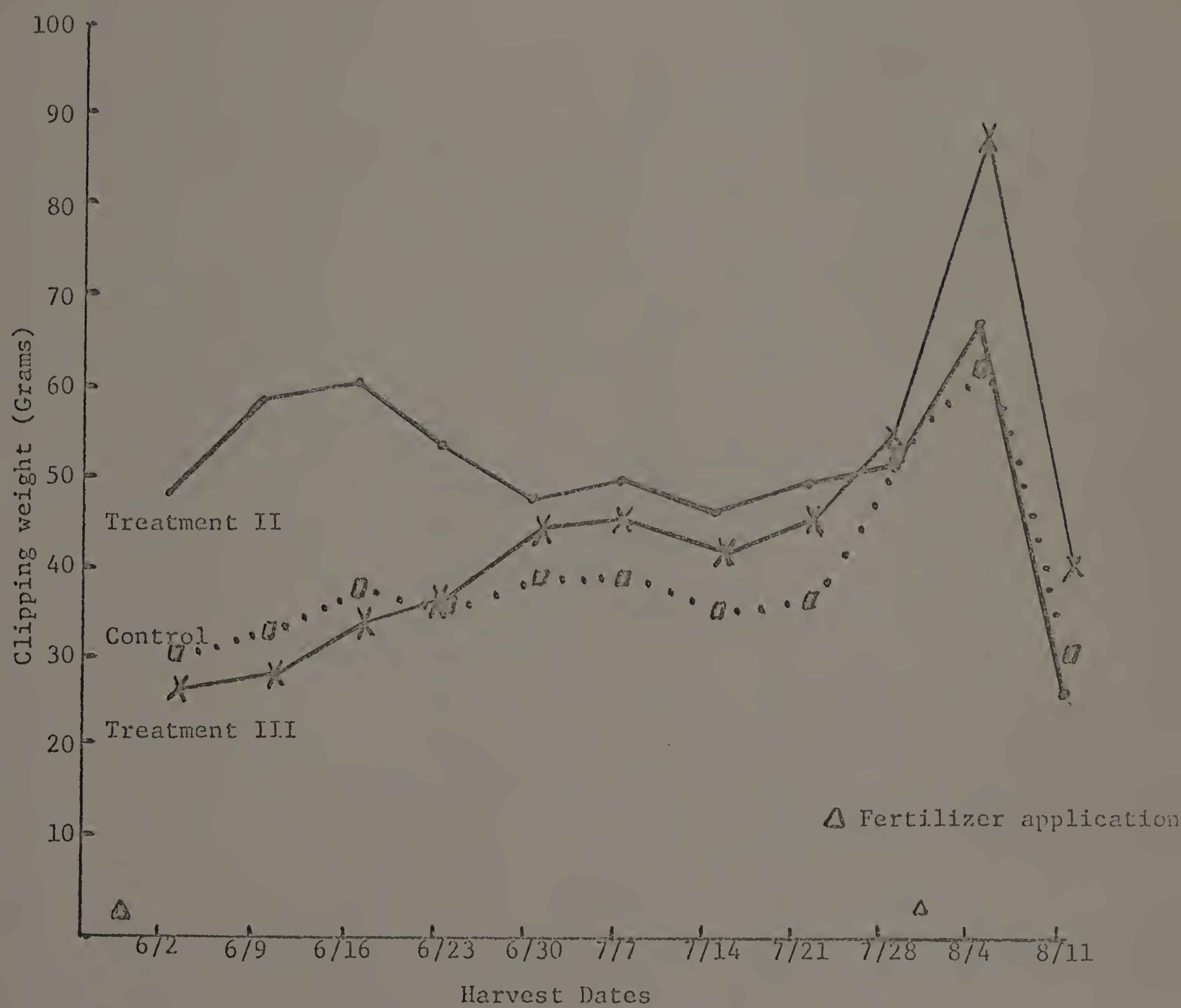

Figure 3. A comparison between Treatments II (2 lbs. n) and III (grass clippings) as they affect clipping weights of Kentucky bluegrass.

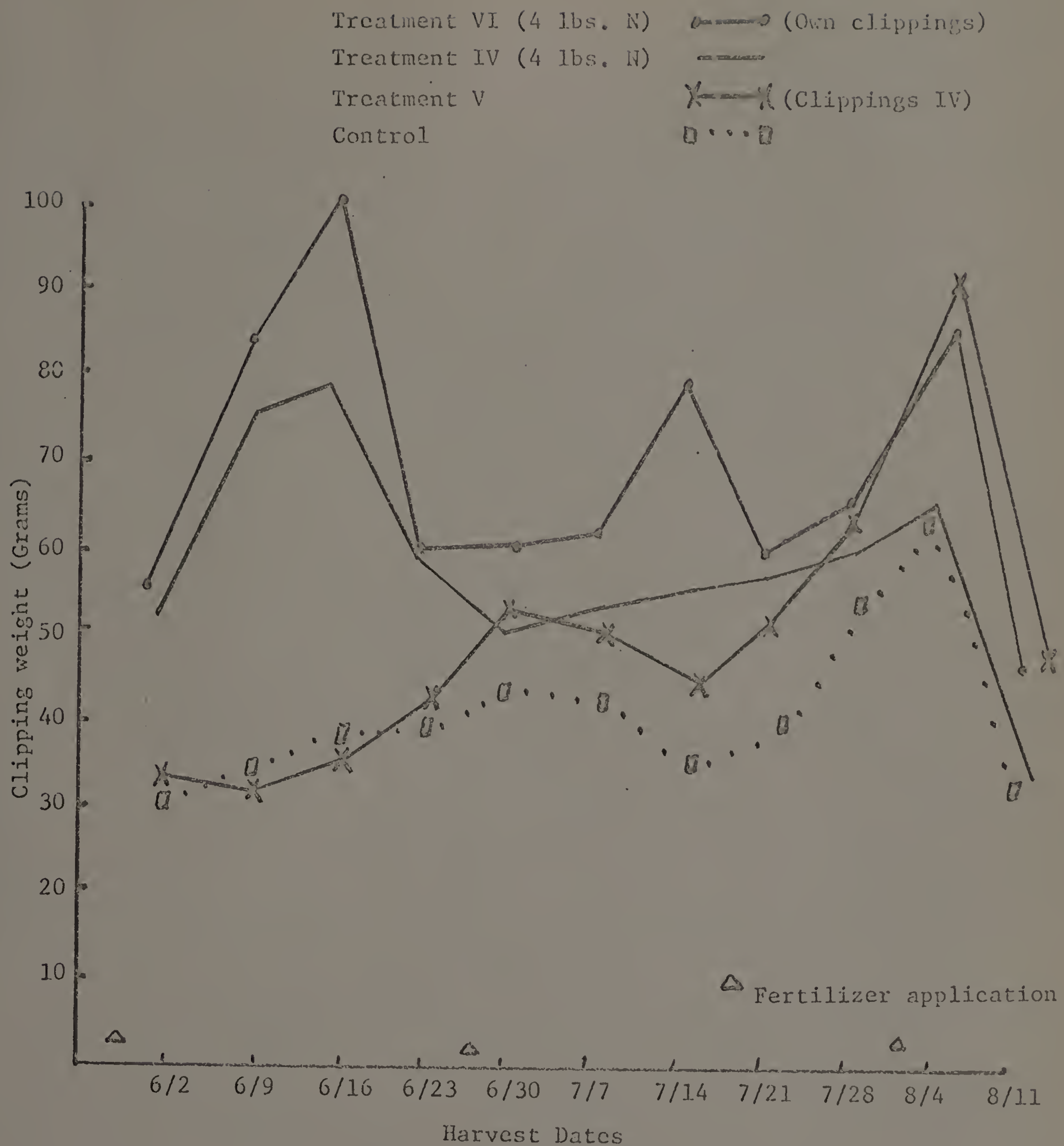

Figure 4. A comparison of harvested topgrowth between Treatments IV, 4 lbs actual N, Treatment V, clippings from IV, and Treat- VI, 4 lbs actual N and own clippings returned.

Table 11. Treatments, dry weight of clippings in grams for the first two weeks of June, July and August and total yearly weights.

Treatment		Average dry weight (in grams) of harvested clippings	Total yearly weight
I	Unfertilized Check	June 33.2 July 34.5 Aug. 45.9	1273
II	2 lbs. actual N	June 54.4 July 48.3 Aug. 48.3	1696
III	Clippings from II	June 28.2 July 43.5 Aug. 64.9	1473
IV	4 lbs. actual N	June 64.9 July 56.0 Aug. 52.2	1945
V	Clippings from IV	June 31.4 July 49.5 Aug. 70.0	1624
VI	4 lbs actual N plus own clippings returned	June 69.2 July 69.9 Aug. 66.5	2265

Table 12. Treatments, dates of harvest and the average amounts of nitrogen in harvested Delta Kentucky bluegrass clippings.

Treatment		Amounts of Nitrogen (in grams) Harvest Dates												*Treatment
		6/2	6/9	6/16	6/23	6/30	7/7	7/14	7/21	7/28	8/4	8/11	Total	Mean
I	(Control)	2.81	3.50	3.80	3.88	4.64	4.08	3.91	4.03	5.31	6.92	3.55	46.43	4.22A
II	(2 lbs. actual N)	5.87	6.88	6.41	6.24	5.27	6.12	6.07	5.59	5.82	7.13	3.42	64.82	5.89B
III	(Clippings from II)	2.45	2.89	3.41	4.40	5.59	5.30	5.14	5.92	6.61	12.27	5.48	59.26	5.39AB
IV	(4 lbs. actual N)	7.77	10.73	9.92	6.88	6.37	7.35	7.53	7.35	7.05	7.90	4.74	83.59	7.59C
V	(Clippings from IV)	2.83	3.31	3.55	4.92	6.29	5.83	5.07	6.28	7.02	10.77	6.21	62.08	5.64B
VI	(4 lbs. actual N and own clippings returned)	8.09	11.25	12.60	7.60	7.89	8.60	10.45	7.78	8.27	10.96	6.56	100.05	9.09D

*Treatment means followed by the same letter do not differ significantly at the 5 percent level using Duncan's Multiple Range Test.

Analysis of variance for Table 14.

Source	df	Mean Sq.	F
Date	10	2.68	26.51*
Date X Treatment	50	0.8076	7.99*
Error B	120	0.1011	

* Significant at 0.01 level.

Table 13. Treatments, dates of harvest and the average amounts of potassium in harvested Delta Kentucky bluegrass clippings.

	Treatment	Amounts of Potassium (in grams) Harvest Dates 6/2	6/9	6/16	6/23	6/30	7/7	7/14	7/21	7/28	8/4	8/11	Total	*Treatment Mean
I	Control	2.03	2.39	2.68	3.06	3.05	2.88	2.30	2.57	3.33	4.32	2.20	30.81	2.80A
II	2 lbs. actual N	3.49	4.95	4.74	4.73	3.80	3.68	3.33	4.00	3.95	4.94	2.01	43.62	3.96BC
III	Clippings from II	1.80	2.02	2.64	3.11	3.77	3.32	3.03	3.69	4.29	6.67	3.34	37.68	3.42AB
IV	4 lbs actual N	4.04	7.65	6.80	5.07	4.26	4.10	4.46	4.74	4.63	5.05	2.80	53.60	4.87CD
V	Clippings from IV	1.99	1.78	2.53	3.45	4.39	3.85	3.21	4.19	5.24	6.80	3.78	41.21	3.75AB
VI	4 lbs. actual N and own clippings re-turned	4.23	7.97	8.24	5.27	5.50	4.93	5.41	5.11	4.89	6.46	3.60	61.61	5.60D

* Treatment means followed by the same letter do not differ significantly at the 5 percent level using Duncan's Multiple Range Test.

Analysis of variance for Table 14.

Source	df	Mean Sq.	F
Date	10	1.209	24.67*
Date X Treatment	50	0.345	7.04*
Error B	120	0.049	

* Significant at 0.01 level.

Table 14. Treatments, average weights in grams and differences in amounts of nitrogen and potassium found in unfertilized turf as compared to all other treated turf in the first two weeks of June, July and August

Treatments	Average weight (in grams) as recorded for the first two weeks of the month	N	K	N	K
I Unfertilized check plot	June	3.16	2.21	0.00	0.00
	July	3.99	2.59	0.00	0.00
	August	5.24	3.26	0.00	0.00
II 2 lbs. actual N	June	6.38	4.22	3.22	2.01
	July	6.10	3.51	2.11	0.92
	August	5.28	3.43	0.04	0.17
III Clippings from II	June	2.67	1.91	-0.49	-0.30
	July	5.22	3.18	1.21	0.59
	August	8.88	5.01	3.64	1.75
IV 4 lbs. actual N	June	9.25	5.85	6.09	3.64
	July	7.44	4.28	3.45	1.69
	August	6.32	3.93	1.08	0.77
V Clippings from IV	June	3.07	1.89	0.09	-0.33
	July	5.68	3.53	1.69	0.94
	August	8.49	5.29	3.25	2.03
VI 4 lbs. actual N and own clippings returned	June	9.67	6.10	6.51	3.89
	July	9.53	5.17	5.54	2.58
	August	8.76	5.03	3.52	1.77

Summary and Conclusion

The appearance of turf can be rapidly enhanced by the application of fertilizer. The breakdown and release of nutrients from clippings is a slow process which may take two or three months, thus a change in appearance is delayed.

The growth rate of turf is rapidly increased but of short duration following soluble fertilizer applications. When clippings are applied to a turfstand the growth rate increases very slowly and may be long lasting.

It is quite evident from this study that applications of both fertilizer and organic matter together, would produce a moderately growing lawn with some asthetic value.

The application in too great a quantity of succulent clippings may provide a media suitable for the development of disease. It appears that this can be controlled by limiting the amounts of clippings left on the turf.

A well fertilized healthy lawn is usually weed free. This can result from fertilizer applications and/or returned clippings.

Thatch formation is enhanced greatly by the accumulation of clippings on a turfstand. It can also be the result of excessive fertilizer applications. If both are controlled the problem can be avoided.

Turf clippings apparently can be beneficial as a source of nutrients to lawn turf. If the grass plants are well fertilized their clippings are a source of nitrogen, phosphorus, potassium and possibly other elements released over an extended period.

The amounts of nutrients returned to the grass in clippings are substantial. They increase as the fertility level of the clipping source increases. They are a valuable source of nutrients and should be considered in a fertilization program.

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VII. APPENDIX

Appendix Table 1. Dried clipping weights harvested from replicates of the control plots.

Dates of Harvests	Weights of clippings (in grams) Series 1	2	3	4	5
May 28			Not Cut		
June 30	1.4	1.6	1.3	1.2	0.9
July 25			Not Cut		
August 18	1.6	1.5	1.4	1.9	1.1
September 20	1.1	1.1	1.5	1.3	1.0
October 24	0.9	1.3	1.0	0.8	1.3

Appendix Table 2. Dried clipping weights harvested from replicates of Treatment I for use in Treatment II and dates applied to unfertilized boxes of turf.

Dates of Harvests	Weight of clippings (in grams) Series				
	1	2	3	4	5
May 28	2.0	2.4	1.9	2.0	2.1
June 30	0.5	0.8	0.4	0.9	0.5
July 25	0.4	0.5	0.7	0.3	0.4
August 18	1.1	0.7	0.9	0.8	1.2
September 20	0.7	0.9	1.0	0.6	0.7

Appendix Table 3. Dried clipping weights harvested from replicates of Treatment II.

Dates of Harvests	Weight of clippings (in grams) Series				
	1	2	3	4	5
May 28			Not Cut		
June 30	1.4	1.3	1.5	1.4	2.1
July 25			Not Cut		
August 18	2.7	2.9	3.1	3.0	2.8
September 20	0.9	1.4	1.7	1.1	1.5
October 24	3.2	2.9	3.5	3.1	3.0

Appendix Table 4. Dried clipping weights from replicates of Treatment III for use in Treatment IV and dates applied to unfertilized boxes of turf.

Dates of Harvests	Weight of clippings (in grams) Series				
	1	2	3	4	5
May 28	1.6	2.0	1.4	1.7	1.8
June 30	0.8	0.7	0.6	1.0	0.6
August 18	0.7	0.9	1.2	0.5	1.0
September 20	1.0	0.7	0.8	0.5	0.9
October 24	0.4		1.0	0.1	0.8

Appendix Table 5. Dried clipping weights harvested from replicates of Treatment IV.

Dates of Harvests	Weight of clippings (in grams) Series				
	1	2	3	4	5
May 28			Not Cut		
June 30	2.1	1.7	2.6	2.4	2.5
July 25	1.6	1.5	1.8	2.1	1.9
August 18			Not Cut		
September 20	2.3	2.1	2.5	1.9	2.6
October 24	3.1	2.9	3.2	3.0	2.8

Appendix Table 6. Dried clipping weights from replicates of Treatment V for use in Treatment VI and dates applied to unfertilized boxes of turf.

Dates of Harvests	Weight of clippings (in grams) Series 1	2	3	4	5
May 28	1.9	2.0	2.4	2.1	2.3
June 10	1.5	0.9	0.7	1.8	1.4
June 30	0.9	0.8	0.7	0.9	0.6
July 25	1.4	1.0	1.6	1.1	1.5
August 18	1.1	1.4	1.0	1.3	1.6
September 20	1.6	1.3	1.4	1.7	1.1
October 24	1.0	0.8	0.7	1.3	1.4

Appendix Table 7. Dried clipping weights harvested from replicates of Treatment VI.

Dates of Harvests	Weight of clippings (in grams) Series 1	2	3	4	5
May 28			Not Cut		
June 30	1.5	1.7	1.4	1.8	1.7
July 25	2.4	2.8	2.5	3.1	3.1
August 18	1.9	1.8	1.9	2.1	1.6
September 20	2.0	1.9	2.2	1.8	1.7
October 24	2.5	1.9	2.6	2.4	2.2

Appendix Table 9. The percent nitrogen found in clippings for the last three months of the greenhouse study.

	August	September	October
Treatment I 2 lbs. actual n	1.11	.80	NC*
Treatment II Clipings I	.57	.72	1.56
Treatment III 4 lbs. actual n	.90	1.40	1.40
Treatment IV Clippings III	1.27	1.16	2.55
Treatment V 7 lbs. actual n	5.20	5.85	3.67
Treatment VI Clippings V	1.60	2.90	3.93
Treatment VII 9 lbs. actual n	8.20	8.32	8.63
Treatment VIII Control	.57	NC	.16

* NC = Not Cut

Appendix Table 10. Treatments, dates of harvest and percent of actual N in Kentucky bluegrass clippings (Field Study).

	Treatment	Average Percent Nitrogen for Three Replicates Harvest Dates										
		6/2	6/9	6/16	6/23	6/30	7/7	7/14	7/21	7/28	8/4	8/11
I	Control	3.06	3.25	3.46	3.73	3.83	3.43	3.98	4.05	3.52	3.64	4.08
II	2 lbs. actual n	4.08	3.58	3.56	3.87	3.88	4.07	4.38	4.18	3.70	3.59	4.15
III	Clippings from II	2.95	3.11	3.31	3.96	4.05	3.53	4.16	4.40	3.97	3.92	4.46
IV	4 lbs. actual n	3.19	4.59	4.09	4.27	4.26	4.48	4.34	4.31	3.94	3.78	4.46
V	Clippings from IV	3.03	3.06	3.36	3.93	3.12	3.75	3.98	4.10	3.86	3.83	4.43
VI	4 lbs. actual n and own clippings returned	4.88	4.57	4.14	4.27	4.39	4.66	4.54	4.44	4.29	4.18	4.82

Appendix Table 11. Average percent potassium in each harvest (Field Study).

	Treatment	Harvest Dates										
		6/2	6/9	6/16	6/23	6/30	7/7	7/14	7/21	7/28	8/4	8/11
I	Unfertilized (Control)	2.17	2.25	2.51	2.95	2.75	2.41	2.60	2.61	2.28	2.28	2.56
II	2 lbs. actual n	2.42	2.82	2.63	2.91	2.81	2.42	2.39	2.70	2.51	2.39	2.41
III	Clippings from Treatment II	2.11	2.38	2.60	2.81	2.71	2.41	2.37	2.72	2.56	2.51	2.72
IV	4 lbs. actual n	2.55	3.27	2.81	3.15	2.83	2.65	2.58	2.76	2.58	2.47	2.67
V	Clippings from Treatment IV	2.15	2.29	2.42	2.74	2.87	2.47	2.47	2.73	2.71	2.46	2.68
VI	4 lbs. actual n and own clippings returned	2.54	3.22	2.74	2.96	3.05	2.70	2.32	2.86	2.31	2.45	2.65

Appendix Table 12. Precipitation and daily temperature for the last three months of the field study.

	June 1967		July 1967		Aug. 1967	
Day	Temp. Min.-Max.	Rain Inches	Temp. Min.-Max.	Rain Inches	Temp. Min.-Max.	Rain Inches
1	34 - 79	----	59 - 81	----	62 - 86	0.05
2	45 - 88	----	65 - 82	----	55 - 83	----
3	46 - 87	----	62 - 85	----	66 - 83	0.05
4	48 - 88	----	55 - 82	1.00	69 - 78	0.24
5	48 - 87	----	59 - 82	0.57	68 - 83	----
6	54 - 86	----	52 - 75	0.02	62 - 82	0.07
7	54 - 83	----	47 - 82	----	55 - 82	----
8	61 - 81	----	55 - 85	----	59 - 81	----
9	54 - 85	----	64 - 85	----	62 - 81	----
10	60 - 91	----	67 - 90	----	66 - 83	0.18
11	63 - 91	----	65 - 89	----	48 - 82	----
12	64 - 91	----	67 - 86	0.50	54 - 74	----
13	58 - 90	0.37	60 - 85	----	54 - 74	----
14	54 - 74	----	61 - 85	0.07	58 - 80	0.05
15	56 - 84	----	64 - 74	0.48	50 - 85	----
16	62 - 94	----	69 - 75	0.36	52 - 85	----
17	65 - 90	----	55 - 84	----	57 - 85	----
18	64 - 89	0.33	60 - 84	0.82	58 - 87	----
19	58 - 68	1.22	63 - 81	----	64 - 87	----
20	55 - 68	0.40	65 - 81	----	68 - 84	----
21	56 - 68	0.03	65 - 83	----	54 - 79	0.51
22	61 - 77	----	64 - 81	0.03	58 - 81	----
23	65 - 78	1.01	64 - 81	----	50 - 81	----
24	56 - 86	----	68 - 86	0.03	46 - 74	----
25	65 - 86	----	68 - 87	0.08	54 - 73	0.02
26	53 - 85	0.24	60 - 86	0.19	58 - 72	0.25
27	48 - 83	----	55 - 86	----	66 - 82	1.91
28	52 - 84	----	64 - 85	0.82	70 - 80	0.36
29	51 - 83	----	63 - 84	0.24	52 - 81	----
30	57 - 75	0.01	69 - 84	0.03	52 - 84	----
31			59 - 86	----	62 - 84	0.07
Average	55.6 - 83.3		61.7 - 83.3		58.4 - 81.2	
Total		3.61		5.24		3.76

Appendix Table 13. Dried clipping weights from unfertilized Delta Kentucky bluegrass control plots (Treatment 1).

Harvest Dates 1967	Weight of Clippings (in grams) Replications 1	2	3	Total	Average
6/2	39	27	27	93	31.0
6/9	36	33	37	106	35.3
6/16	34	31	44	109	36.3
6/23	37	34	33	104	34.7
6/30	39	39	43	121	40.4
7/7	42	38	39	119	37.3
7/14	20	25	50	95	31.7
7/21	35	24	41	100	33.3
7/28	53	43	55	151	50.3
8/4	52	66	71	189	63.0
8/11	24	24	38	86	28.7

Appendix Table 14. Dried clipping weights from replicates of Treatment 2 (two pounds of actual nitrogen) and dates applied to unfertilized turf.

Application Dates 1967	Weight of clippings (in grams) Series 1	2	3	Total	Average
6/2	55	42	47	144	48.0
6/9	60	64	52	176	58.7
6/16	73	55	53	181	60.3
6/23	60	47	55	162	54.0
6/30	49	43	44	146	48.7
7/7	60	50	41	151	50.3
7/14	49	45	45	139	46.3
7/21	55	40	55	150	50.0
7/28	51	50	56	157	52.3
8/4	62	66	70	208	69.3
8/11	33	21	28	82	27.3

Appendix Table 15. Dried clipping weights from Delta Kentucky bluegrass plots receiving clippings from turf fertilized with two pounds of actual nitrogen (Treatment 3).

Harvest Date 1967	Weights of Clippings (in grams) Replications 1	2	3	Total	Average
6/2	35	24	23	82	27.3
6/9	35	27	25	87	29.0
6/16	46	30	26	102	34.0
6/23	50	29	32	111	37.0
6/30	52	42	44	138	46.0
7/7	55	40	42	137	45.7
7/14	60	30	34	124	41.3
7/21	42	40	53	135	45.0
7/28	62	50	56	168	56.0
8/4	84	79	103	266	88.7
8/11	44	24	45	123	41.0

Appendix Table 16. Dried clipping weights from replicates of Treatment IV (four pounds of actual nitrogen) and dates applied to unfertilized turf.

Application Dates 1967	Weight of Clippings (in grams) Series 1	2	3	Total	Average
6/2	63	50	45	158	52.7
6/9	84	77	73	234	78.0
6/16	72	98	72	242	80.7
6/23	62	48	51	161	57.0
6/30	59	42	49	150	50.0
7/7	67	50	47	164	54.7
7/14	60	65	48	173	57.3
7/21	63	57	51	171	57.0
7/28	60	64	55	179	59.3
8/4	60	73	75	208	69.3
8/11	33	36	36	105	35.0

Appendix Table 17. Dried clipping weights from Delta Kentucky bluegrass plots receiving clippings from turf fertilized with four pounds of actual nitrogen (Treatment 5).

Harvest Date 1967	1	2	3	Total	Average
6/2	33	33	27	93	31.0
6/9	37	36	22	95	31.7
6/16	42	44	18	104	34.7
6/23	51	48	27	126	42.0
6/30	56	49	48	153	51.0
7/7	64	50	41	155	51.7
7/14	54	41	36	131	47.0
7/21	52	50	51	153	51.0
7/28	69	59	65	193	64.3
8/4	96	94	91	281	93.6
8/11	50	46	44	140	46.6

Appendix Table 18. Dried clipping weights from Delta Kentucky bluegrass plots receiving four pounds of actual nitrogen, its own clippings, and dates applied. (Treatment 6).

Application 1967	Weight of Clippings (in grams) Replications 1	2	3	Total	Average
6/2	60	61	45	166	55.3
6/9	109	75	65	249	83.0
6/16	133	87	83	303	101.0
6/23	50	70	50	179	57.7
6/30	63	55	62	180	60.0
7/7	68	64	53	185	61.7
7/14	102	66	66	234	78.0
7/21	53	71	53	177	59.0
7/28	69	63	61	193	64.3
8/4	86	78	99	263	87.6
8/11	44	42	50	136	45.3

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by

H. Peter Wood

Approved as to style and content by:

Joseph Troll

Dr. Joseph Troll, Thesis Chairman

F. W. Southwick

Dr. Frank W. Southwick, Head of Department
Plant and Soil Sciences

William G. Colby

Dr. William G. Colby, Member

John H. Baker

Dr. John H. Baker, Member

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